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1 24. Sediment Control

1.1 Introduction

1.1.1 Description of Technique

Sediment problems can originate nearly anywhere in a watershed. In response, sediment control often takes place throughout the watershed, including measures as diverse as changes in land use practice, stream bank treatment, road redesign or decommissioning, stormwater management improvement and removal of sediment from stream channels. This technique covers techniques aimed at reducing the amount of sediment reaching a stream as well as removing it once it arrives. The approaches are categorized as: out-of-channel techniques; streambank stabilization; and in-stream sediment detention.

Out-of-channel techniques involve managing point and non-point sediment sources. Approaches include forest road decommissioning, riparian zone restoration, stormwater management improvements, upland erosion control measures in agricultural lands, wildlands, construction sites, street cleaning, grazing restrictions, and other land use practice modifications.

Placeholder - Bank stabilization…{USFWS INSERT TEXT}

In-stream sediment detention involves creating sediment "traps" to retain sediment for storage or removal. Common reasons for sediment removal include excess sediment input in upstream reaches, excess localized deposition caused by local infrastructure (such as bridges), channelization, and general channel bed aggradation. The latter two conditions may or may not be associated with elevated sediment inputs to the system.

The goal of in-stream sediment detention is to remove excess sediment from the stream system, and is generally not cost effective if excess sediment source reduction measures (out of channel techniques described above) are not conducted in concert with constructing sediment traps. Sediment traps are a technique of last resort when source control is not possible and other, more natural techniques are not feasible. Most sediment traps are temporary measures, and don't constitute natural channel restoration or rehabilitation.

With regard to in-channel sediment detention, this text is intended to supplement the AHG Sand and Gravel Mining document white paper. Sediment detention is included as a technique in that guideline.

1.1.2 Physical and Biological Effects

1.1.2.1 Out-of-stream Sediment Control and Streambank Stabilization

Placeholder: Add discussion of the possible benefits and impacts of reduced sedimentation problems, and make case that bank stabilization and non-point source control are effectively same problem and solution – they are both affecting inputs. Physical benefits include reduction of channel instability associated with aggradation, improved sediment transport balance. Biological impacts include improved spawning habitat quality due to reduced siltation, improved habitat complexity through restored natural transport and sorting. List additional benefits and impacts.

1.1.2.2 In-stream Sediment Detention

Sediment detention basins are used to trap excess sediment that exists within the stream system. As such, they can be useful tools in the recovery of sediment-laden systems. However, even properly designed detention basins must be used with care, for their potential negative effects include: interruption of debris and bedload transport continuity; associated scour and incision downstream; and segregation of bed load into a coarse fraction (which is trapped) and a fine fraction (which may pass through the trap and contribute to downstream habitat siltation). Large traps may act as dams and create a discontinuity in interactions along the stream length Ward, J.V. and J. A. Stanford (1983). Impacts may include impediments to passage of aquatic organisms, alteration in floodplain interactions downstream, storage of nutrients in the reservoir, and other important yet subtle impacts.

1.1.3 Application of Technique

1.1.3.1 Out-of-channel Sediment Control

Out-of-channel techniques cover a broad range of watershed management strategies. Application of out-of-channel techniques should be focused on eliminating excessive sediment inputs based on the land use practices and natural conditions unique to each watershed. Examples include reforestation, modification of agricultural practices, decommissioning of forest roads, and stabilization of steep upland slopes.

1.1.3.2 Streambank Stabilization

{Placeholder - USFWS: insert streambank treatment text}

1.1.3.3 In-stream Sediment Detention

In-stream detention methods include structures and bed features intended to trap sediments, including dams, pools (ponds), and debris jams. In-stream detention techniques can be applied in transport or depositional reaches, alluvial or non-alluvial reaches.

Simple storage of sediment is less desirable than short term collection/storage followed by removal. Sediment traps tend to disrupt sediment transport continuity until the traps are full. Simple trapping and storage of sediment may or may not allow for re-establishment of balanced transport continuity once the trap is full, depending on site conditions and trap design. In addition, the trapped sediment is susceptible to re-mobilization in the event of structural failure of the trap or, in some cases, simply due to the occurrence of a large runoff event.

Depositional reaches tend to widen as sediment accumulates. Channels within depositional areas tend to be dynamic, and bank erosion rates high. Trapping and removal of sediment in these reaches can slow or stop the rate of lateral expansion and erosion in these reaches. Many stream reaches in Washington are naturally depositional and form braided channels or deltas at confluences or grade breaks. While these features are unpredictable and may interfere with land use, they provide important ecological functions Stanford, J.A. and J. V. Ward (1993) and play a role in disturbance which has been found to contribute to salmonid restoration Reeves, G.H. et al. (1995).

1.2 Scale

Out-of-channel and bank stabilization techniques can be used to control excessive sediment inputs on any size drainage area. In-stream sediment detention basins have typically been applied on small to medium size streams. On larger rivers, sediment is often removed from the channel without employing sediment detention basins (i.e., from gravel bars).

1.3 Risk and Uncertainty

1.3.1.1 Out-of-channel Sediment Control

Out-of-channel techniques cover a broad range of watershed management methods. Generally, there is little or no risk associated with controlling non-point sediment sources, when those sources are the result of human modification of the watershed. Similarly, there is little uncertainty in the method. Watershed management techniques intended to reduce non-point sediment are well-documented and proven.

1.3.1.2 Streambank Stabilization

{Placeholder: USFWS: insert streambank treatment text}

1.3.1.3 In-stream Sediment Detention

In-stream sediment detention basins offer little risk to public safety, assuming they do not include any significant damming of the stream. Their location within urban vs. non-urban settings does not necessarily effect risk or uncertainties. Risk to adjacent property and infrastructure should be insignificant if sound planning and design are employed when creating a detention basin. Due to high natural variability in sediment transport conditions and individual stream conditions, there is uncertainty concerning trapping efficiency and the size of particle actually trapped. This is particularly true with small traps where the potential is high for sediment to pass through the trap.

1.4 Data Collection and Assessment

1.4.1.1 Out-of-channel Sediment Control

Data collection and assessment for out-of-channel techniques typically requires some level of watershed assessment to determine point and non-point sediment sources. Refer to
Chapter 3 for further detail and references for watershed assessment. Discussion of data collection and assessment requirements for specific out-of-channel techniques is included in the references listed in Methods and Design (below).

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1.4.1.2 Streambank Stabilization

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1.4.1.3 In-stream Sediment Detention

Planning and design of in-stream sediment detention basins should be preceded by careful assessment of sediment conditions within the stream, including evaluation of the natural forces at work and the biological impacts of the sediment.

- *Biological habitat needs and sediment transport/deposition characteristics in subject reach.* Planning for in-stream sediment detention should include biological assessment of the impacts of sediment in the project reach. This analysis will help define/identify sediment-related problems, and aid in planning for a solution. Particularly important in this regard are impacts to downstream spawning and macroinvertebrate habitats and other discontinuity effects associated with dams Ward, J.V. and J. A. Stanford (1983),Vannote, R.L. et al. (1980)

- *Watershed assessment* Because sediment detention basins exert significant impacts on stream systems, sediment detention basins should be considered a "last resort" technique to be used when other options are not feasible. Prior to implementing in-stream sediment detention, sediment sources and reasons why source control is not possible should be identified.

- *Hydrology and hydraulics* Planning for in-stream sediment detention will require estimation of sediment volume being transported through the stream. This will typically require hydrologic, hydraulic, and sediment transport assessment and/or analyses. In order to estimate sediment volumes using some methods, detailed hydrologic statistics, including mean daily flows over the period of record, will be needed. Additionally, a hydraulic model will have to be developed to determine sediment shears within the channel at varying flows. This typically requires detailed surveying of cross-sections throughout the channel. Hydrologic, hydraulic and sediment transport analyses are detailed in the Hydrology, Hydraulics, and Sediment Transport Appendices.

- *Sediment supply and volume* An estimate of the average annual sediment yield can be made by integrating the stream flow duration curve with the sediment discharge rating curve at the inlet to the trap. This method is detailed in EM 1110-2-4000 (USACE, 1989) and by Julien (1995). SAM can be used for these calculations. The average annual sediment yield can be used for an initial planning level estimate of frequency of maintenance. Estimates of sediment yield are difficult to make and may have little to do with actual yield in any given year. Sediment flux is episodic due to failure of channel bank and bed features as well as variable colluvial process. Sediment volumes are highly dependent on magnitude of flow and a single low frequency flood may fill the trap. Monitoring and maintenance should include documentation of prior stream flow conditions, sediment yield (volume collected) and size distribution of bed load material collected in the trap. Records of dredge volumes may give an indication of sediment discharge.

- *Fluvial Geomorphic Assessment.* A geomorphic analysis of the natural stream processes and anthropogenic actions affecting the reach, and historic conditions, should be conducted in order to assess the appropriateness of a detention basin in the geomorphic and historic context. The effects of channelization are often what drive landowners to feel they need sediment traps. One half of the sediment basins in Western Washington are there because of channelization. Channels that have been straightened and cut off from their flood plains lack the sediment storage and transport characteristics of natural channels that have configured themselves to efficiently handle their sediment discharge. Other naturally depositional stream reaches often have adjacent infrastructure that need sediment traps for protection until a long-term solution can be implemented.

1.5 Methods and Design

1.5.1 Out-of-channel Sediment Control

Commonly used out-of-channel techniques and corresponding references are shown in the table below.

Out-of-channel Technique	***Suggested Reference***
Road decommissioning and logging BMP's	Washington Department of Natural Resources Forest Practice Act
Riparian zone restoration	EPA, US Army Corps of Engineers
Stormwater management, street cleaning	Washington Department of Ecology Stormwater Manual (updated manual for Western Washington is released, Eastern Washington Manual is in preparation.
Livestock grazing restrictions, upland sediment detention basins and erosion control measures, agricultural BMP's	Natural Resources Conservation Service USDA Forest Service Bureau of Land Management

1.5.2 Streambank Stabilization

{Placeholder - USFWS: insert streambank treatment text}

1.5.3 In-stream Sediment Detention

The basic concept involved in sediment detention is to create an area of relatively low velocity in which sediment will settle out of the flow. Sediment basins are typically designed with a downstream constriction that creates an upstream pool. This is typically accomplished by creating a flow control device in the stream channel.

1.5.3.1 Site Selection for Sediment Basins

Placeholder – site selection considerations for locating sediment basins

If possible, basins should be located where the channel has a natural grade break or constriction that increases the natural tendency for sediment to accumulate. In addition (especially if the sediment is to be periodically removed) the site should be readily accessible to equipment such as front end loaders, excavators, and dump trucks. Areas immediately upstream from road culverts may make good sediment basin locations, provided the basin and associated sediment deposits will not impair the function or structural stability of the culvert. If such a culvert is not large enough to pass flood water, sediment and debris, or is a barrier to fish passage, then it should be replaced before the sediment pond is installed. Don't let an existing culvert determine pond characteristics - design the outlet to accomplish the goals of the project. It is possible that increasing culvert capacity may change the deposition pattern in such a way that a sediment trap is not necessary.

The profile of the entire reach should be considered when designing a sediment basin. Fish passage must be maintained up to the ten percent exceedance flow for periods when fish migrate through the reach according to the Revised Code of Washington (RCW) 75.20.060. Transitions between the various elements should be smooth, both horizontally and vertically. No abrupt water surface changes greater than one foot at all flows and pond conditions. Grade control should be established downstream to for a smooth transition as well as scour protection at the outlet of the flow control device. At least one grade control should be installed 25 to 50 feet downstream of the basin outlet to maintain the bed elevation. Grade control upstream will be necessary to prevent headcut when the pool is excavated. The first grade control immediately upstream of the pond must extend down to at lest 1 foot below the maximum depth of excavation to prevent failure from undermining or sloughing. This control acts as a dam supporting the upstream channel when the pond is empty.

1.5.3.2 Flow Control Structures

Placeholder – discuss various devices used to control flow

Flow control devices include weirs and slots. A weir may be constructed out of a variety of materials, including rock, wood, concrete, etc. and used to backwater a basin to collect gravel. A slot is more efficient since pool volume increases more rapidly with higher flow when sediment discharge is greatest. Slots form a more concentrated jet that may scour the downstream channel. Design should account for debris build up in the slot. Be sure to match the stage-discharge relationships for the various flow control structures involved in the project. Slots, weirs and channels may all have different depths for a given flow. Changes in water surface elevations between these structures should not be greater than one foot to provide fish passage and discourage deep scour.

In some cases, particularly in smaller streams, natural woody debris can be used to create a sediment trap (Figure 1). In fact, adding woody debris in source and transport reaches can be a means of addressing sedimentation problems in depositional areas.Bilby, R.E. (1984),Bilby, R.E. and J. V. Ward (1989),(1985),Haas, A.D. (1997),Megahan, W.F. (1993?),Montgomery, D.R. et al. (1996),Nakamura, F. and R. J. Swanson (1993),Potts, D.F. and B. K. M. Anderson (1990),Shields, F.D. et al. (2000)

1.5.3.3 Basin Design

The size and shape of a sediment retention basin depends on the stream size, sediment load, and various other site conditions. Evaluate bedload material to determine particle sizes through pebble counts, bed sediment sampler or bulk screening. Trapping efficiency will change depending on the volume of sediment in the basin. This means that as the basin fills depth decreases and flow velocity increases larger and larger particles pass through the trap and the volume trapped decreases. Insure that critical particle sizes are trapped at the pool volumes expected under normal circumstances. Other factors may prove to be important. These may include pool length, expansion rate, depth and shape. A mathematical approach to sedimentation can be found in (Haan, et. al. 1994),(Lopez 1978),(Raukivi 1990)

An example is shown in Figure 2. Sediment retention basins are typically located on the main stream channel. Width, depth, length and shape of the basin should work with existing site constraints and allow for efficient gravel removal. A few different shapes have been tried. The first is basically a tear drop shape (Figure 2) where the effects of expansion of the channel width and backwater by the downstream hydraulic control combine to promote the deposition of streambed material. Expansion rates of 1:2.6 to 1:4 have been tried. These traps are successful although expansion as independent variable has not been thoroughly evaluated. Another trap has been designed to take advantage of the hydraulic characteristics of a meander bend; the trap is configured to look like a bend and sediment is deposited on the "point bar" of the trap and a pool is maintained around the outside of the bend (the pool drain is located along the outside and is not buried by errant deposits). Aesthetic and habitat concerns are less important if a basin is temporary, but long-term or permanent basins should take these factors into account. Habitat enhancement should not be a part of trap design and features that attract fish or encourage spawning should be eliminated.

Uncertainties in design primarily include the structural stability of the weir, and the "trapping ability" of the basin. The weir should be relatively low and simple. In all but the most simple cases, a hydraulic engineer should conduct the design. The areas backwatered by the weir should be large and low gradient enough to effectively trap the desired quantity of sediment.

1.5.3.4 Fish Passage through Basins

Placeholder – fish passage design considerations for devices and basins

Some sediment basins require extensive outlet structures and fish passage facilities. Large drops between the pool exit and the downstream bed elevation lead to complex solutions involving concrete dams and fishways.

1.5.3.5 Sediment Removal

Basin design should include a bypass ditch or pipe in which to divert flow during basin maintenance and sediment removal. Both ends of the bypass should be blocked when it is not in use to prevent fish stranding. It is conceivable that a bypass channel could be designed to function as off channel habitat, although no projects to date have taken advantage of this.

A sluice gate or flashboard riser should be included in the bottom of the sediment basin to allow its drainage (in conjunction with fish removal) prior to sediment removal. Locate this drain in a place that is not likely to become overwhelmed with sediment and remains clear prior to excavation. When repeated sediment removal is expected, an access road and work pad should be provided for excavation equipment and truck access.

The *Sand and Gravel Mining White Paper* contains additional information on sediment detention.

1.5.3.6 Delta Trap Concept

Another concept, which has not been built but shows great promise is the delta or alluvial fan configuration (Parker et. al. A and B, 1998). This concept takes a form ubiquitous in nature and attempts to apply it to sediment control. An area is set aside with the proper slope and dimensions and is let to aggrade naturally. As sediment deposits in one area, the main flow channel moves to another location lower in elevation. This pattern continues, forming a complex network of old and new channel locations and layers of deposited materials (Thorne et. al. 1997). The delta trap would be maintained by excavating a shallow area on one side and allowing flow to reclaim the lowered area. It is likely that a project like this would take up more area than conventional sediment traps although retain some of the biological benefits of the natural formation.

1.5.3.7 Decommissioning Sediment Basins

Placeholder – design considerations for decommissioning sediment basins

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1.6 Project Implementation

1.6.1 Permitting

Out-of-channel techniques may or may not require permits. Concerns involved in permitting bank protection and sediment detention basins mirror the general considerations discussed elsewhere in this document. Permitting for bank protection projects is detailed in the Integrated Streambank Protection Guidelines. Permitting sediment basins is likely to require a justification for trap and a discussion of the life of project (nearly all sediment traps are temporary). A complete discussion of required permits is presented in Chapter section 4.6.

1.6.2 Construction

1.6.2.1 Out-of-channel Sediment Control

Construction considerations for out-of-channel sediment control measures vary as widely as the techniques themselves. Discussion of construction requirements for out-of-channel techniques is included in the references listed in Methods and Design.

1.6.2.2 Streambank Stabilization

{USFWS: insert streambank treatment text}

1.6.2.3 In-stream Sediment Detention

Construction concerns for sediment detention basins mirror the general considerations discussed elsewhere in this document. In addition, it is recommended that all weirs and structural elements that can be buried by deposited sediment be marked to avoid damage during sediment removal. A complete discussion of construction considerations for in-channel projects is presented in the Construction Appendix.

1.6.3 Cost Estimation

1.6.3.1 Out-of-channel Sediment Control

Cost of out-of-channel sediment control measures vary as widely as the techniques themselves. Discussion of cost of out-of-channel techniques is included in the references listed in Methods and Design.

1.6.3.2 Streambank Stabilization

{USFWS: insert streambank treatment text}

1.6.3.3 In-stream Sediment Detention

The primary tasks in sediment removal are excavation and hauling. Rates for these tasks vary by region and by haul distance. For example, excavator and operator rates can vary from approximately $X/hour in the Seattle area to $X/hour in northeast Washington. Local rates can generally be estimated based on conversation with a few local contractors. The circumstances and location of the work can also effect cost significantly. When working in difficult-to-access sites and/or space-constrained conditions, construction crews and equipment may require twice (or more) as much time as they would to complete tasks under ideal conditions.

1.6.4 Monitoring and Tracking

1.6.4.1 Out-of-channel Sediment Control

Appropriate monitoring strategies for out-of-channel sediment control measures vary. Discussion of monitoring techniques is included in the references listed in Methods and Design.

1.6.4.2 Streambank Stabilization

{USFWS: insert streambank treatment text}

1.6.4.3 In-stream Sediment Detention

Sediment detention basin volume should be monitored so that sediment removal can be initiated as they near operating capacity. Trapping efficiency and the size of particle trapped changes with the level of sediment deposited in the basin. This is particularly important for trapping smaller sized particles since their settling velocity is slower and residence time in the basin decreases as it fills (Roberson 1988). In addition, structural integrity of basin components, basin effects on local streambanks, and downstream effects (such as increased erosion) should be monitored. Monitoring may include any or all of the following elements:

- Visual inspections (periodic, and after storm events);
- Section and Profile Data;
- Document stream flows between maintenance/monitoring operations;
- Record the volume of sediment taken out the trap;
- Bed Substrate Data (e.g. grain size distribution);
- Photo Points;
- Reach Based Fish Snorkeling to identify impacts to habitat;
- Spawning Surveys, document location of redds (this is often not a part of spawning surveys) to detect impacts to d/s reach.

1.6.5 Contracting Considerations

Concerns involved in contracting mirror the general considerations discussed elsewhere in this document.

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1.7 Operations and Maintenance

1.7.1.1 Out-of-channel Sediment Control

Operation and maintenance requirements for out-of-channel sediment control measures vary. Discussion of operation and maintenance of out-of-channel sediment control measures is included in the references listed in Methods and Design.

1.7.1.2 Streambank Stabilization

{USFWS: insert streambank treatment text}

1.7.1.3 In-stream Sediment Detention

Operation and maintenance play a major role in successful detention basin application. With the exception of structures intended to be permanent and naturally maintained (e.g., large woody debris placed in low-order streams to enhance sediment retention), the majority of sediment detention structures will require operation and maintenance effort. As mentioned previously, detention basin volume should be monitored so that sediment removal can be initiated as they near operating capacity. In addition, structural integrity of basin components, basin effects on local streambanks, and downstream effects (such as increased erosion) should be monitored.

A maintenance schedule and procedures should be a part of the design and contracting documents, and as a provision in the original HPA (the Hydraulic Project Approval permit). The schedule should require the use of a checklist to insure that all procedures are followed, specifically stating who is to perform the maintenance and the details of that activity. Modifications to that schedule should be made in cooperation with all the interested parties. Check at least after each flood since sediment flux is episodic and may vary dramatically from storm to storm and year to year.

In addition to monitoring, repair, and removal of sediment, removal of the basin and associated structures should be addressed included as operation and maintenance duties.

1.8 Examples

1.8.1.1 Out-of-channel Sediment Control

{need examples}

1.8.1.2 Streambank Stabilization

{USFWS: insert streambank treatment text}

1.8.1.3 In-stream Sediment Detention

Conceptual drawing created by Bob Barnard (Figure 2)

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Five well-documented WDFW sediment detention basin projects on tributary streams.

1.9 References

1.10 Photo and Drawing File Names

Bozeman office is having scanner problems, thus drawings are not yet available for this technique

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Haan, C. T., B. J. Barfield, and J. C. Hays. 1994. *Design Hydrology and Sedimentology for Small Catchments*.Academic Press, San Diego, California.

Haas, A.D. 1997. Coarse sediment storage by large woody debris in small, steep streams of the North Cascades. University of Washington Senior Thesis.
Notes: "Each cubic meter of key piece wood in spanning jams stores from six to eleven times its volume in coarse sediment."

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Notes: An average of 15 times more seidment was stored behind obstructions than was delivered to the mouths of the drainages as annual average sediment yield. Storage behind obstructions is an important component of the overall sediment routing through forested drainage basins.

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Notes:cycles of disturbance and recovery are part of natural systems. Salmonids are adapted to these cycles. Cycles last from decades to centuries. Disturbance must be recognized as an integral component of any long-term strategy. In the long term, a static reserve system alone is unlikely to meet the requirements of anadromous salmonids.

Roberson, J. A., J. J. Cassidy, and M. H. Chaudhry. 1988. *Hydrualic Engineering*.Houghton Mifflin Co. Boston, MA.
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USFS/BLM road decommissioning standards (CORRECT REFERENCE NEEDED)

USDI Bureau of Land Management, Grazing Management in Riparian Areas. Riparian Area Management Series: Technical Reference 1737-4, Denver, 1989